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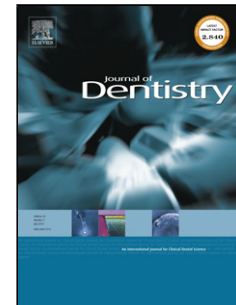
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Title: **Impact of Time Pressure on Dentists' Diagnostic Performance.**

Short Title: Time pressure and dentists' performance

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Abstract:

Objectives: Although stress is prevalent amongst dentists, there is a paucity of data on the impact of stressors on dentists' clinical performance. To address this gap in the literature, the aim of the present study was to explore the role of time pressure, representing one common stressor, on dentists' radiographic diagnostic performance.

Methods: Forty dentists were randomised to examine and provide a radiographic report on two sets of radiographs (six bitewings in each set) under two conditions on a cross-over basis: time-pressure vs. no-time-pressure. The radiographic report of an experienced consultant was considered the gold standard against which participants diagnostic decisions were compared to calculate sensitivity and specificity. Participants rated their stress after each experimental condition using a 100 mm visual analogue scale (VAS).

Results: The VAS scores for stress were significantly higher in the time pressure condition vs. no time pressure condition (mean: 55.78 versus 10.73, $p < 0.0001$), indicating that the time pressure acted as a source of stress. Dentists' diagnostic performance was affected; the sensitivity was significantly lower under time pressure (median: 0.50 versus 0.80, $p < 0.0001$), but by contrast, the median diagnostic specificity was 1.00 under both conditions.

Conclusions: Time pressure negatively impacts one aspect of dentists' diagnostic performance, namely sensitivity (increased diagnostic errors and omissions of pathology), which can potentially affect patient safety and the quality of care delivered. However, time pressure was found to have less influence on diagnostic specificity.

Clinical Significance: The present study demonstrated a significant deterioration of dentists' diagnostic performance (sensitivity) under time-pressure when examining bitewing radiographs. Diagnostic errors may put patient safety at risk, with patients potentially being harmed if pathology is missed. Such errors can have medicolegal implications on the dentists' practice.

Keywords: 1) Radiography, Bitewing; 2) Stress, Psychological; 3) Diagnostic Errors; 4) Dental Caries; 5) Alveolar Bone Loss; 6) General Practice, Dental.

Introduction

Dentistry is recognised as a stressful profession [1-3]. Work related stress has been associated with dentists' developing mental health issues such as depression and an elevated risk of burnout [4]. The prevalence of burnout amongst the profession varies amongst studies with some reporting that 2.5% of the dental workforce is severely burnt-out [5] and others indicating that 26% of the dentists are at high risk of both emotional exhaustion and depersonalisation [6].

Dental professionals encounter numerous sources of stress beginning in dental school [7] and postgraduate training [8] that can continue or escalate during their practicing

lives. The most often reported stressors are dealing with difficult and demanding patients, running behind schedule and time pressures, followed by staff issues and pressures from third parties [1, 9-15]. Although dentists perceive time pressure as an important stressor which may potentially influence their clinical decisions [16, 17], a systematic review of the dental literature identified no experimental studies that assessed the impact of stress or different stressors on dentists' performance [18]. In contrast, there is ample evidence from other medical domains showing that time pressure affects decision making and diagnostic accuracy of healthcare professionals as well as their psychomotor performance and procedural skills [19-23]. Whether time pressure has similar impact on dentists' performance, however, is an open and important question.

Dental complaints and negligence claims have been reported to be on the rise [24], with 9% of the dental claims relating to diagnostic errors [25], whilst, incorrect interpretation of diagnostic tests account for 37% of medical claims [26]. Bitewing radiographs are the most common radiograph utilised in general practice to assist the dentist to form a diagnosis and inform their treatment decisions [27-29]. Bitewings are often taken at relatively regular intervals, whenever there is a suspicion of dental caries and/or periodontal disease [29, 30]. If time pressure has a negative impact on dentists' diagnostic ability, this may result in sub-optimal care being provided and potentially put patient safety at risk.

Therefore, given the paucity of research in this topic, the aim of this paper was to investigate the impact of time pressure on dentists' diagnostic performance when viewing dental bitewing radiographs.

Material and Methods

Design

This was a randomised cross-over study. Primary care dentists examined and provided a radiographic report on two sets of radiographs A and B (six bitewings in each set) under two conditions: time-pressure vs. no-time-pressure. Dentists were randomised to one of four groups based on the order in which they examined the two sets of radiographs (A then B, or B then A) and the order in which the examination conditions were applied (time pressure then no time pressure, or no time pressure then time pressure). The radiographic report of an experienced consultant was considered the gold standard against which participants diagnostic decisions were compared to calculate sensitivity and specificity. The study received ethical approval (16/17-704) from the University of Plymouth Research Ethics committee, England, UK.

Recruitment

Primary care dentists in the Southwest of England were invited to participate in the study. Invitation leaflets and information sheets were sent to potential participants via post, or emails through different professional dental networks.

Radiographs

Twelve digital radiographs were selected from the Peninsula Dental Social Enterprise's clinical patient records, to develop two sets of dental bitewing radiographs (A and B). Each set was composed of six radiographs. Between the two sets of radiographs, the radiographs' assessed diagnostic difficulty, the number of pathological features, and the types of different pathologies were distributed evenly. Each set was composed of three easy and three difficult radiographs. The level of

difficulty was established via a pilot study using six experienced (8-20 years) dentists. The number and type of pathological features were determined by a specialist in restorative dentistry (TO'B) who provided a detailed radiographic report. The report was also reviewed by a general dentist (AP). This report was used as gold standard radiographic report.

Time Pressure

The observation time for each of the twelve radiographs in the time pressure condition was determined by the pilot study, using the equation suggested by Ordonez and Benson: $TP = TM_P - SD_P$ [31]. TM_P corresponded to the mean observation time for each radiograph in the pilot study, while SD_P to the standard deviation for each radiograph in the pilot study. The time pressure limits applied on the examination of the study radiographs varied from 8 to 38 seconds.

Experimental Groups

Four different counterbalanced experimental test groups were developed on Qualtrics Research CORE™ interface and a web link was generated for each group (see Figure 1). Block randomisation was used to ensure that equal numbers of participants were allocated in each of the four experimental groups [32]. STATA version 10 was used for the random sequence generation and the size of blocks varied between 4 and 8. This stage was completed by an independent researcher (DM) and the sequence and size of blocks remained unknown to the principal researcher (AP).

Procedure

The study took place in either a quiet non-clinical room on the premises of the University of Plymouth or individual dental practices during non-operating hours. The

study was delivered electronically on a computer and took on average forty minutes to complete.

After informing the participants about the procedure, a written consent form was signed and the participants were allocated to one of the four groups. The group they were allocated to was revealed after opening a sealed envelope. The corresponding Qualtrics web link then was opened on the computer. Prior to commencing the study, the participants undertook a practice exercise which mimicked the experimental condition. Next, participants were instructed to examine each radiograph and to take notes on a blank piece of paper (pen and paper were provided to all participants). In the time pressure condition, a countdown clock was present on the screen (Figure. 2). After viewing each radiograph they were asked to provide a report on any pathology they identified and be tooth and site specific. To reduce variations of reporting style or terminology among participants, participants were asked to indicate the types of pathology they identified, based on a list that was provided to them (Table 1). Although the examination of the radiographs was subject to time pressure on half of all occasions, there was no time restriction applied to the participants while they typed the radiographic reports for either of the conditions. After each condition, the participants were asked to complete two 100 mm electronic visual analogue scales (100 mm VAS) indicating the level of stress they experienced during the task and their perception of the difficulty of the task (Figure 3). At the end of the study, participants completed a number of demographics questions.

Data were extracted from each radiographic report by the principal researcher (AP). The completed data collection forms were double-checked by another researcher (MBD) against the participants' reports to ensure that no transcription errors had occurred. Each participant's responses were compared to the gold-standard

radiographic report. For each report the true-positive (TP), true-negative (TN), false-positive (FP) and false negative (FN) decisions were calculated. For each radiographic report the participant's diagnostic sensitivity and specificity were calculated according to the following diagnostic equations: Sensitivity = $TP / (TP + FN)$, and Specificity = $TN / (TN + FP)$ [33].

Statistical analysis

All analyses were performed using SPSS version 24 (IBM SPSS Statistics) and the significance level was set at $p < 0.05$. The difference between VAS values (self-reported stress and difficulty) between the two conditions were analysed using paired *t*-tests. Mann-Whitney U tests were used to assess the difference between the diagnostic sensitivity and specificity between the two conditions for all the types of pathology and for caries and bone loss recognition alone. The analyses were performed by condition globally across all the study radiographs and also by individual radiograph.

Results

Participants

Forty general dental practitioners from the Southwest of England took part in the study. Their experience ranged from 1 to 35 years with a mean of 17 years (16.92 ± 12.58 (SD) years). The participant characteristics are depicted in Table 2.

Stress and perceived difficulty of the task

To examine whether the time pressure manipulation worked, participants' stress and perceptions of the difficulty of the task were compared between the two conditions. The data showed a statistically significant difference ($p < 0.001$) in the VAS scores for

perceived stress under the time-pressure (Mean =55.78, SD=25.74) compared to the no time-pressure (Mean =10.73, SD=12.06) condition. Similarly, participants rated the experimental task significantly more difficult ($p<0.001$) under the time pressure condition (Mean=65.43, SD=25.11), compared to the no time pressure condition (Mean=14.83, SD=12.63).

Impact of time pressure on diagnostic performance in global radiographic reporting (all pathologies and features)

To evaluate the impact of time pressure on performance, we compared diagnostic results under the two conditions globally. A Mann Whitney U test indicated that median diagnostic sensitivity was significantly worse ($p<0.001$) under time pressure (Median=0.50) compared to under no time pressure (Median=0.80), for all radiographs combined. Further, Cohen's effect size value ($r = 0.41$) suggested a moderate effect of time pressure on the dentists' diagnostic ability. A statistically significant ($p=0.036$) albeit negligible effect ($r = 0.07$) of time pressure on dentists' diagnostic specificity was observed. The median value for specificity for both conditions was 1.00.

Impact of time pressure on radiographic caries recognition.

A Mann Whitney U test indicated that participants' global ability to correctly diagnose lesions indicative of caries radiographically (sensitivity) was significantly worse ($p<0.001$) under time pressure (Median=0.6) compared to no time pressure (Median=1). Cohen's effect size value ($r = 0.29$) suggested a moderate effect of time pressure on dentists' diagnostic ability. In contrast, the dentists' ability to correctly identify caries free sites radiographically, did not appear to be affected by time pressure (Median for both conditions 1.00, $p=0.443$).

Impact of time pressure on radiographic bone loss recognition.

We also evaluated whether time pressure negatively affected participants' ability to recognise and report on radiographic evidence of bone loss. In particular, the participants were asked to report on radiolucencies indicative of horizontal, vertical and furcation bone loss. A Mann Whitney U test indicated that participants' global ability to correctly diagnose bone loss and bony defects radiographically (sensitivity) was significantly worse ($p < 0.001$) under time pressure (Median=0.33) compared to no time pressure (Median=1.00). Cohen's effect size value ($r = 0.35$) suggested a moderate effect of time pressure on dentists' diagnostic ability. In contrast, dentists diagnostic specificity did not appear to be affected by time pressure (Median for both conditions 1.00, $p = 0.353$).

Impact of time pressure on dentists' diagnostic performance for each radiograph.

The impact of time pressure on diagnostic performance was compared for each of the 12 different radiographs separately to check whether the results were consistent across all radiographs (Tables 3 and 4). The participants' median diagnostic sensitivity was significantly worse for 10 out of 12 of the radiographs under the time pressure condition, but their median diagnostic specificity was not significantly different between the experimental conditions for any of the radiographs. The median sensitivity values varied from 0.21 to 1.00 for the time-pressure condition, and from 0.50 to 1.00 for the non-time-pressure condition. The median specificity was high in both conditions ranging from 0.98 to 1.00 across all the radiographs.

When focusing on caries recognition, in contrast, in only two (A4 and B1) of the radiographs did the median diagnostic sensitivity of the dentists deteriorate under time

pressure statistically significantly (by 50% and 10% respectively). In the reports of six radiographs no statistically significant difference between dentists median diagnostic sensitivity was observed in relation to time pressure. The sensitivity could not be calculated for the reports of four radiographs as there was no caries-related pathology present. For all the radiographic reports the median specificity was high (Median ranging from 0.91 to 1.00) and no statistically significant differences were detected between the conditions.

For bone loss recognition, the participants' median diagnostic sensitivity was significantly worse for 6 out of 9 of the radiographs under the time pressure condition. The median sensitivity values varied from 0.33 to 1.00 for the time-pressure condition, and from 0.50 to 1.00 for the non-time-pressure condition. The sensitivity could not be calculated for the reports of three radiographs as there was no bone loss present. Lastly, the median specificity did not differ significantly for either condition and it was 1.00 for all the radiographs.

Discussion

Time pressures occur frequently in general dental practice and dentists have reported that time constraints may influence the decisions they make in their day to day practice [11, 17]. This study examined the influence of time pressure on the dentists' diagnostic performance when examining dental bitewing radiographs in a simulated environment. To the best of our knowledge, this is the first study to empirically examine the impact of time pressure on dentists' performance [18].

Our data clearly reveal a significant deterioration in dentists' diagnostic sensitivity both in terms of identifying all the reporting items in the given radiographs (30% median

reduction in sensitivity), recognising radiolucencies that are indicative of caries (40% median reduction in sensitivity), and recognising radiographic signs of periodontal destruction (67% median reduction in sensitivity). However, no clinically relevant differences were observed for changes in specificity.

It has been proposed that when dentists examine dental bitewing radiographs, they use a 'script match' based on cumulative previous experience with similar clinical presentations of health and disease [34]. This script match is known as pattern recognition [34]. Our findings partially support the dual process theory of decision making which suggests that two distinct psychological processes are at work when a clinician is diagnosing a case: System 1 non-analytical reasoning and System 2 analytical reasoning [35, 36]. Non-analytical reasoning, also called heuristic reasoning, depends on rapid, unconscious pattern recognition during which prior examples or illness scripts stored in long-term memory are retrieved. This type of reasoning is quick, intuitive, implicit, contextualized, and typically efficient in diagnosing routine cases [35, 36]. Thus, dentists may employ System 1 when examining radiographs, but its efficiency may be impaired under time pressure and become vulnerable to errors. On the other hand, System 2 reasoning is slow, reflective, sequential, effortful, and particularly used to diagnose complex cases [35, 36]. Dentists, therefore, may employ System 2 reasoning when collating information from the patient's history, symptoms and clinical presentation to come up with a definite clinical diagnosis.

Our findings are also in line with previous studies indicating a negative impact of time pressure on diagnostic performance among other groups of health care professionals. A randomised controlled experiment by ALQahtani et al., for example, reported that internal medicine residents made on average 37% more diagnostic errors under time pressure than their peers in the control no-time-pressure group [22]. Similarly, in a

simulated study by Tsiga et al., primary care medical practitioners gave significantly more incorrect responses when they answered questions related to diagnosis and management of different respiratory infection clinical scenarios under time pressure than under no time constraints [23].

Time pressures faced in general dental practice, therefore, may have a negative impact on the quality of care delivered. Diagnostic errors may put patient safety at risk, with patients potentially being harmed if pathology is missed. This may lead to unnecessary pain, the need for more complex treatment such as endodontic treatment, or even loss of the tooth. Besides, bitewing radiographs offer important diagnostic information with regard to alveolar bone destruction allowing the practitioner to detect and monitor any deterioration in periodontal health and support [37]. Medico-legal defence unions report an increasing number of claims related to allegations of failure to diagnose and treat periodontitis [38, 39]. Our study indicated that time pressure may lead to failure to identify and report radiographic signs of caries and periodontal disease (such as vertical and furcation bone loss) which may in turn have detrimental medico-legal implications on the dentists' practice.

Allowing longer appointment times when dentists are planning to take and report on radiographs and/or re-assessing and reviewing their radiographs and radiographic reports when they are not under time constraints may mitigate the risk of diagnostic errors, but would naturally have resource implications. Therefore, changes in dental guidelines, policy and regulation might be warranted to facilitate longer appointment times. However, this would be difficult to implement since policy-makers and regulators do not specify how long appointments should take. Practitioners decide on the length of time required to undertake dental appointments and this decision represents a complex interplay between how long the practitioner feels is necessary

to undertake the task and the efficiency (and therefore cost/profit) that they are attempting to achieve. Further evidence on the role of time pressure on dentists' efficiency, patient experience and patient safety is required in order to inform the debate and influence policy makers' decisions [40].

Strengths and limitations

In our study, participating dentists were working in a variety of primary care settings (private, NHS, mixed practices and community services) and had a broad range of experience (1-35 years) which increases the generalisability of the findings of this study. The counterbalancing and randomisation procedures ensured that the complexity and the order of the tasks were balanced and unaffected by participants' learning or by any potential fatigue by the end of the study. Thus, the observed difference in diagnostic performance is most likely primarily due to the experimental manipulation (time pressure). Moreover, the time pressure limits applied were calculated from a pilot study based on previously validated methods [31]. The statistically significant difference in VAS scores between the two conditions confirmed that the time pressure in the present study acted as a stressor factor amongst the participants.

Whether the time pressure limits used in the present study reflect the time constraints that dentists may face in clinical practice is an open question as currently we are lacking such data from general dental practice. In addition, the simulated nature of the experimental task does not represent fully what happens in a real clinical environment. Dentists in practice may face more than one stressor simultaneously (time pressure, demanding patient, difficult treatment). These are conditions which are difficult to replicate in a simulated experimental setting. Stressful encounters with real

patients, however, are difficult to predict and raise ethical concerns if manipulated in the real setting. Nonetheless, despite these limitations, our study provides a vital indication regarding the likely impact of time pressure on dentists' performance.

Implications for Future Research

Future studies can build upon the present study by using different types of radiographs and accompany each radiograph or set of radiographs with a clinical scenario (e.g. vignette, clinical photographs). The use of adjunctive clinical information or scenarios in future studies would allow exploration of how different priming information may affect dentists' diagnostic decisions and increase the applicability of the findings to clinical practice. The deterioration in sensitivity, but not specificity is consistent with practitioners missing information, rather than misinterpreting information. However, whilst we have observed these changes, the mechanisms that underpin them remain hypothetical and need to be explored empirically. Eye-tracking technology, being widely used in psychology and human factors research, can be used to assess the dentists' information processing strategies under time pressure versus no-time pressure. [41]. Employing eye tracking technology in future studies may give a better insight into the potential underlying mechanisms (cognitive or behavioural) explaining any observed difference in performance between the two conditions. Understanding these mechanisms may also facilitate and inform the development of tools to decrease the risk of diagnostic errors, such as decision support systems.

Given the paucity of experimental research on this topic, future studies are also warranted to evaluate the impact of time pressure on other aspects of dentists' performance such as treatment planning, communication and psychomotor skills. These research findings could inform the future development of appropriate

educational, patient safety or quality improvement interventions to address performance issues.

Conclusion

The present experimental study demonstrated that when examining dental bitewing radiographs in a simulated environment, dentists missed pathological features (sensitivity). The deterioration in sensitivity (30% for all pathological features, 40% for caries related pathology and 67% for periodontal disease related pathology) was not only statistically but also clinically significant. However, dentists' ability to correctly identify sound sites and teeth free of pathology (specificity) was not materially affected.

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ACCEPTED MANUSCRIPT

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Figures:**Figure. 1: Counterbalancing.**

TP:Time Pressure, NTP No time pressure, A: Set A of radiographs, B: Set B of radiographs

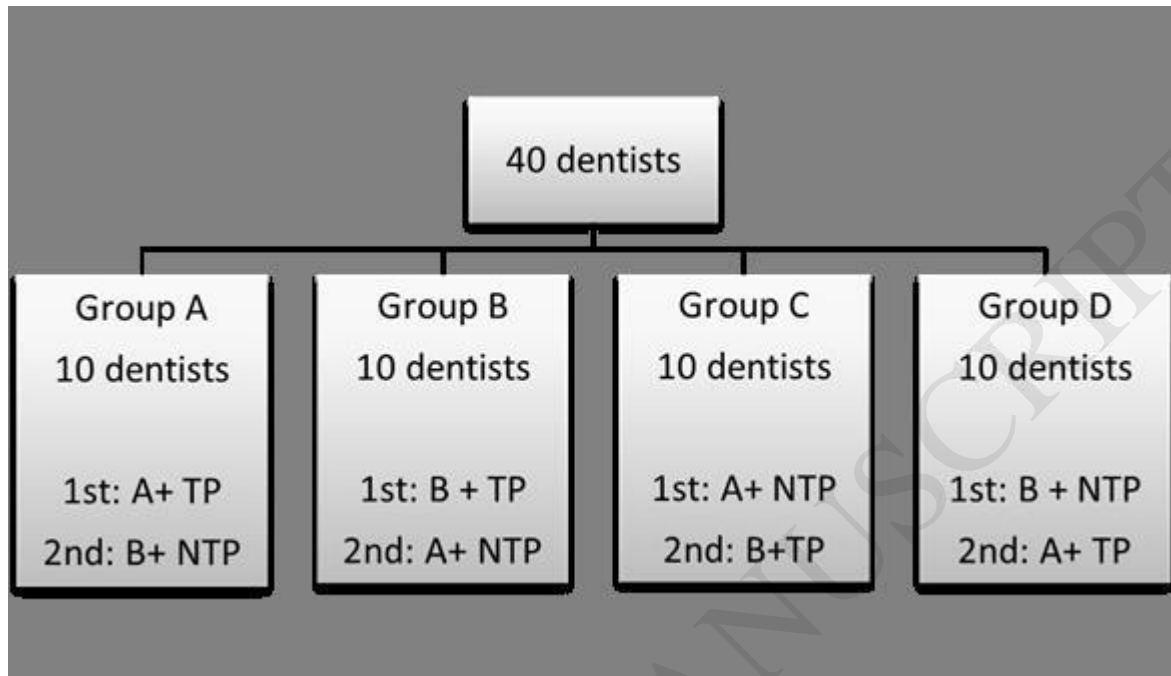


Figure 2: Delivery of the study

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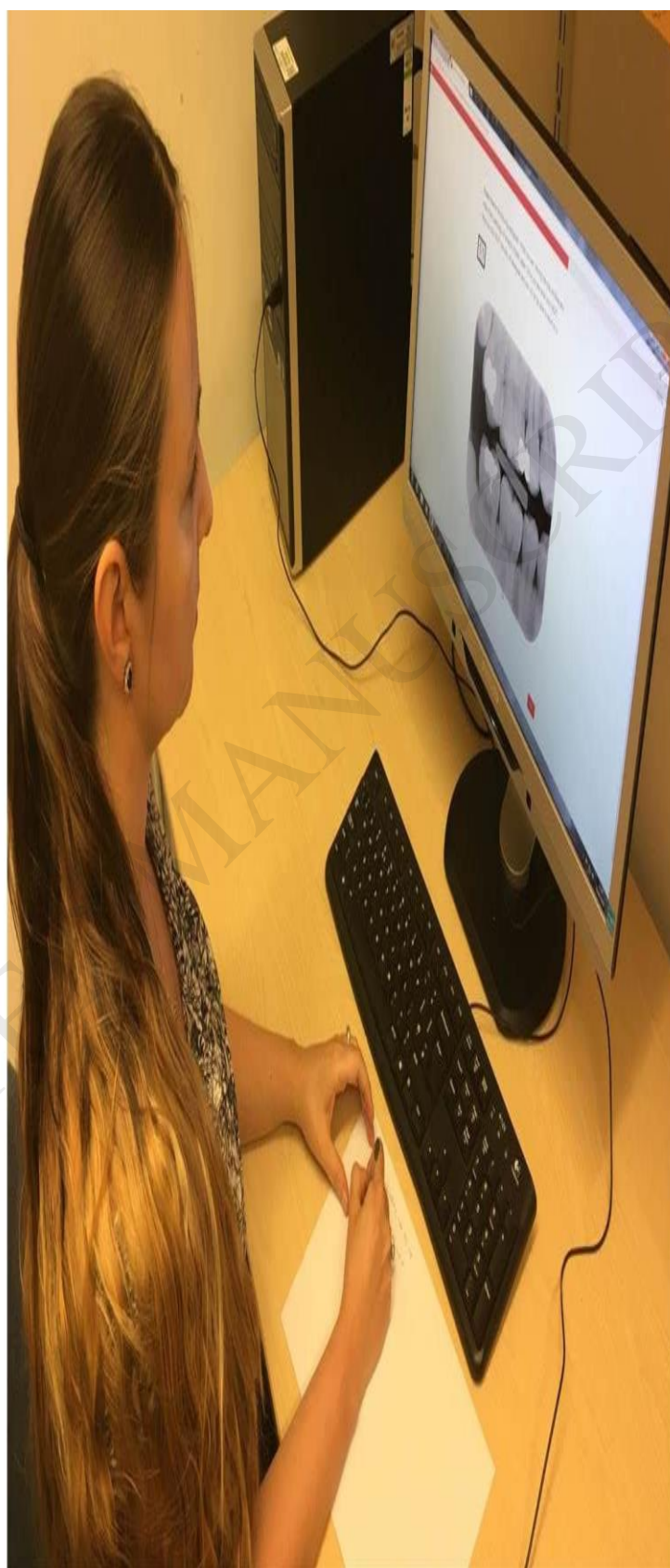
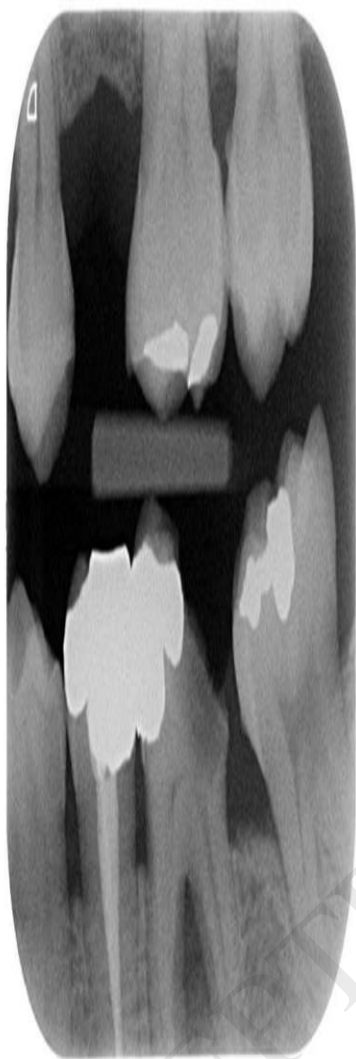


Figure 3: Electronic VAS scales used in the study. The marker can be moved across the scale (0-100) to indicate the participants' stress level and level of difficulty they experienced under each condition.

How stressful did you find this task? Please use the scale of 0 to 100 below where 0 is not stressful at all and 100 is the worst imaginable level of stress.

not at all stressful 0 10 20 30 40 50 60 70 80 90 100 extremely stressful



How difficult did you find this task? Please use the scale of 0 to 100 below where 0 is no difficulty at all and 100 is the greatest level of difficulty imaginable.

not difficult at all 0 10 20 30 40 50 60 70 80 90 100 extremely difficult

Click to write Choice 1



>>

Tables:**Table 1: Reporting Radiographic Items**

any radiolucency indicative of caries
any defective restorations
any overhangs of restorations
any bone loss
any angular bony defects
any furcation involvement lesions
any retained roots and
any impacted teeth

Table 2: Participant characteristics

Participant Characteristics		Frequency (n)	Percentage (%)
Gender	Male	21	53.0
	Female	19	47.0
Type of Practice	Private	10	25.0
	NHS	10	25.0
	Mixed	13	32.5
	Community	7	17.5
Employment	Full-time	23	57.5
	Part-time	17	42.5
Postgraduate Qualifications	Yes	22	55.0
	No	18	45.0

Table 3: Median Sensitivity and Specificity values for Set A radiographs under the two experimental conditions (time-pressure vs no time-pressure)

Table 3: Median Sensitivity and Specificity values for Set A radiographs under the two experimental conditions (time-pressure vs no time-pressure)

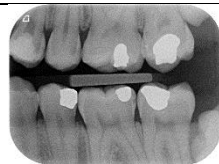
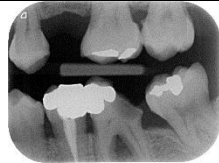




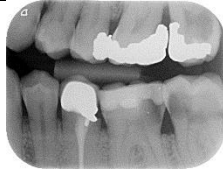


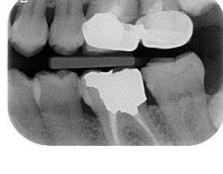


Radiograph (Set A)			Sensitivity			Specificity		
			Time Pressure (Median)	No Time Pressure (Median)	P value	Time Pressure (Median)	No Time Pressure (Median)	P value
A1		Global	0.60	1.00	<0.0001	1.00	1.00	0.076
		Caries	0.66	1.00	0.006	1.00	1.00	0.231
		Bone Loss	*	*	*	1.00	1.00	0.799
A2		Global	0.41	0.75	<0.0001	1.00	1.00	0.156
		Caries	1.00	1.00	0.429	1.00	1.00	1.000
		Bone Loss	0.50	0.75	0.183	1.00	1.00	0.602
A3		Global	0.83	1.00	0.003	1.00	0.98	0.602
		Caries	1.00	1.00	0.102	0.96	1.00	0.414
		Bone Loss	1.00	1.00	0.289	1.00	1.00	1.000
A4		Global	0.50	0.83	<0.001	0.99	1.00	0.904
		Caries	0.37	0.87	<0.0001	0.98	1.00	0.841
		Bone Loss	*	*	*	1.00	1.00	0.602
A5		Global	0.55	0.75	0.012	1.00	1.00	0.495
		Caries	*	*	*	0.94	0.94	0.799
		Bone Loss	0.50	0.50	0.183	1.00	1.00	1.00
A6		Global	0.38	0.53	0.174	0.98	0.98	0.478
		Caries	0.44	0.55	0.565	0.94	0.94	0.799
		Bone Loss	0.00	0.5	0.028	1.00	1.00	0.799
		Independent Samples Mann-Whitney U test						
		*The sensitivity could not be calculated for this radiograph as there was not caries/periodontal-related pathology present						

Table 4: Median Sensitivity and Specificity values for Set B radiographs under the two experimental conditions (time-pressure vs no time-pressure)

Radiograph (Set B)			Sensitivity			Specificity		
			Time Pressure (Median)	No Time Pressure (Median)	P value	Time Pressure (Median)	No Time Pressure (Median)	P value
B1		Global	0.60	0.70	<0.0001	0.98	0.98	1.0
		Caries	0.57	0.71	<0.0001	0.95	0.95	0.841
		Bone Loss	0.00	1.00	0.006	1.00	1.00	1.00
B2		Global	0.33	0.66	0.005	1.00	1.00	0.620
		Caries	*	*	*	1.00	1.00	0.799
		Bone Loss	0.33	0.50	0.005	1.00	1.00	0.799
B3		Global	0.50	0.75	0.026	0.98	0.98	0.086
		Caries	0.66	0.66	0.121	0.97	0.95	0.127
		Bone Loss	0.00	1.00	0.030	1.00	1.00	0.758
B4		Global	1.00	1.00	0.277	1.00	0.98	0.02
		Caries	*	*	*	1.00	1.00	0.799
		Bone Loss	*	*	*	1.00	1.00	0.091
B5		Global	0.66	0.83	<0.0001	1.00	1.00	0.583
		Caries	*	*	*	1.00	1.00	0.799
		Bone Loss	0.33	0.50	0.030	1.00	1.00	0.820
B6		Global	0.21	0.50	<0.0001	1.00	1.00	0.968
		Caries	1.00	1.00	0.600	1.00	1.00	0.461
		Bone Loss	0.33	0.66	<0.0001	1.00	1.00	0.799
		Independent Samples Mann-Whitney U test						
		*The sensitivity could not be calculated for this radiograph as there was not caries/periodontal-related pathology present						